Research Article

RELATIONSHIP BETWEEN FLEXIBLE FLATFOOT AND DYNAMIC BALANCE AND KINETIC CHAIN FUNCTION

Darvine Sebastine[1], Dr. Kapila Jain[2], Dr. Elizabeth M. Roy[3], Dr. Sruthi Sathyan.P[4], Dr. Vikash Saini[5], Dr. Rajnandini Dubey PT[6]

[1]Phd Scholar, Department Of Physiotherapy, Jayoti Vidyapeeth Women's University, Jaipur, Rajasthan (drdarvinept@gmail.com)
[2*]Head Department Of Physiotherapy , Urmila Hospital, Jaipur
[3]Associate Professor , Unity College Of Physiotherapy, Mangaluru, Karnataka
[4]Assistant Professor , P.A Institute Of Physiotherapy , Mangaluru
[5]Professor & Principal Symbiosis College Of Physiotherapy, Jaipur
[6]Senior Physiotherapist, Jaipur, Rajasthan

***Corresponding Author: Dr. Kapila Jain**
Email Id: jainkapila1012@gmail.com

Abstract

Kinetic chain function describes the working mechanism of how the joints, muscles, bones, ligaments, tendons, and connective tissues interact in a coordinated manner to generate controlled movements of the human body. The lower extremity operates in a kinetic chain manner, meaning that the movements at one segment affect the positioning, motion, loading, and stability of the adjacent segments. The foot makes up the distal part of the kinetic chain and serves as the link between the body and the ground surface. During standing, walking, running, and other functional activities, the foot absorbs the ground reaction forces and passes them further through the ankle, knee, hip, and pelvis. Dynamic balance is a set of skills that allows maintaining balance and controlling one's body center of mass when either the body itself or the surface on which it stands is in motion. It includes the continuous processing of information from visual, vestibular, and somatosensory systems together with an appropriate response of the neuromuscular system. An important part of this function is the feet as it is the contact point of the body with the ground. The feet provide both a base of support and sensory information about pressure, posture, and movements. Flexible flatfoot might affect dynamic balance due to deformity of the medial longitudinal arch, excessive pronation of the feet, eversion of the hindfoot, changes in plantar pressure distribution, and instability of the feet. Despite the fact that the difference between the groups was not statistically significant, the Core Stability Training group had a better numerical improvement in single-leg balance than the other groups. There was a considerably higher improvement in FPI-6 when foot-specific exercises were performed, which indicates that these exercises had a bigger influence on foot posture.

Keywords: Flexible, Flatfoot, Dynamic, Balance, Kinetic, Chain, Function

1. Introduction

The most lucid understanding of the human foot's role, its maintenance, and its rehabilitation when compromised or absent may be achieved by seeing the foot as both a lever and an anatomical bridge. Its arches are formed from bones, interconnected by ligaments. In the context of a lever, force is exerted in the rear, namely the heel and posterior to the ankle; the pivot point is located at the toes; the load is positioned at the ankle joint, situated between these two points. The calf muscles, positioned above, can either render the arches inflexible or allow for a pliable ascent and descent due to body weight, or they may mobilise part or all of the structure collectively. Besides supporting human weight, it must also serve as the means by which the body is moved. This ought to be effortless, seamless, and elegant.

Consequently, the equilibrium generated by the synchronised function of the muscular supports, with each muscle reacting appropriately to a weight stimulus, is essential for the organ's operation as a cohesive entity. To ensure these structures function well, excessive stress must not be imposed on any single segment of the bridge; similarly, no individual or group of muscles should be overexerted beyond what is reasonable, taking into account their dimensions, anatomical placements, and the mechanical circumstances in which they operate.

Flexible Flatfoot in Adults

The approach to managing adult flexible flatfoot deformity has undergone substantial transformation over the last three decades; so, we shall start with the therapy paradigms from the early 1980s. During that period, it was still considered

feasible to mend the torn posterior tibial tendon (PTT), either by end-to-end suturing or with a Z-type shortening technique. Although this may be theoretically feasible, the issue with this method lies in the failure to acknowledge that the rupture of the PTT is but one aspect of a range of complications associated with adult acquired flatfoot deformity, and hence, these repair attempts were destined to fail. It is possible that employing this method today to achieve comprehensive muscle and skeletal equilibrium of the foot might be a viable therapy option. Many surgeons now overlook the fact that even in a ruptured PTT, viable collagen cells remain. Certain surgeons currently maintain that preserving the repaired posterior tibial tendon (PTT) is beneficial alongside the other supplementary interventions necessary to rectify the deformity and achieve foot equilibrium. During the 1980s, in addition to repairing the PTT, several surgeons executed a flexor digitorum longus (FDL) transfer or a tenodesis of the FDL to the torn posterior tibial tendon (PTT). This lacks anatomical coherence, since the ruptured PTT has a 12mm excursion, whereas a typical FDL tendon has an excursion nearing 2cm, complicating the equilibrium of both tendons' forces. What is the rationale for employing a standard FDL alongside a tenodesis of the tendon in cases of a ruptured PTT? This was, however, the conventional therapy employed in the early 1980s.

The present treatment of the adult acquired flatfoot deformity

No aspect of foot and ankle surgery provokes as much debate as the "suitable" rectification of the adult flexible flatfoot deformity (AFFD). This dispute is significantly related to the several effective procedures that existed for rectifying such abnormalities. During the 1980s, we were misinformed on the pathology and anatomical abnormalities associated with deformities, whether they were flexible or stiff. Consequently, we and several other surgeons opted for a procedure that was rather straightforward. For instance, in cases with flexible flatfoot and posterior tibial tendon rupture, we and other surgeons have employed a calcaneus osteotomy with medial translation, along with a tendon transfer, typically utilising the flexor digitorum longus to compensate for the damaged PTT. This, of course, overlooked the multitude of abnormalities present in the AFFD, especially the several joints on the medial aspect of the foot, which may droop or suffer from arthritis. This principle also pertains to the several forms of forefoot or midfoot abduction, with the apex potentially located at the talonavicular (TN), naviculocuneiform (NC), or tarsometatarsal (TMT) joint.

Biomechanics Of Flexible Flatfoot

Flexible flatfoot is usually called flexible pes planus or pes planovalgus, and it refers to a foot condition where there is flattening of the medial longitudinal arch of the foot with weight-bearing, while the arch can regain its shape once the foot is unloaded. Flexible flatfoot should not be seen from a biomechanics point of view as the anatomical collapse of the arch; instead, it means the change in the way the bones, ligaments, muscles, tendons, plantar fascia, and ground reaction forces interact to form a functionally intact foot during standing and movement. The medial longitudinal arch serves as an important mechanical element that is involved in the process of dispersing the body's weight, absorbing shocks, adjusting the foot to the irregularity of the surface, and transforming the highly mobile foot into a stiff lever of propulsion. In the case when this system is overly compliant or unable to control pronation, the foot will undergo too much deformity with weight-bearing.

The normal foot goes through a process of pronation and supination in sequence during gait. Following the foot making initial contact, some degree of pronation enables it to conform to the ground and act as a shock absorber. Eversion of the subtalar joint occurs, with eversion of the calcaneus and the tendency for the talus to be in a position of plantar flexion and adduction when compared to the calcaneus. The midtarsal joints become unlocked allowing the foot to adjust to the supporting surface.

Kinetic Chain Function

Kinetic chain function describes the working mechanism of how the joints, muscles, bones, ligaments, tendons, and connective tissues interact in a coordinated manner to generate controlled movements of the human body. The lower extremity operates in a kinetic chain manner, meaning that the movements at one segment affect the positioning, motion, loading, and stability of the adjacent segments. The foot makes up the distal part of the kinetic chain and serves as the link between the body and the ground surface. During standing, walking, running, and other functional activities, the foot absorbs the ground reaction forces and passes them further through the ankle, knee, hip, and pelvis. Flexible flatfoot may have its effect on the entire kinetic chain by changing foot alignment and causing excessive pronation. Thus, it is especially important to assess kinetic-chain function in the case of flexible flatfoot.

In essence, the foot appears to have a dual role in locomotion, where it needs to be able to move enough to absorb any

shock and adapt to the terrain while at the same time having enough rigidity to serve as a good lever during propulsion. In the early stance phase, pronation of the foot ensures adaptation of the foot to the ground and energy dissipation. As the body moves forward, the foot pronates more and becomes increasingly rigid in preparation for the push-off phase. In cases of flexible flatfoot, however, there might be problems in achieving this natural shift. The increased eversion of the hindfoot, the collapse of the medial longitudinal arch, and abduction of the forefoot might affect the mechanics of the interaction between the foot and the ground.

Relationship Between Flexible Flatfoot and Dynamic Balance

Dynamic balance is a set of skills that allows maintaining balance and controlling one's body center of mass when either the body itself or the surface on which it stands is in motion. It includes the continuous processing of information from visual, vestibular, and somatosensory systems together with an appropriate response of the neuromuscular system. An important part of this function is the feet as it is the contact point of the body with the ground. The feet provide both a base of support and sensory information about pressure, posture, and movements. Flexible flatfoot might affect dynamic balance due to deformity of the medial longitudinal arch, excessive pronation of the feet, eversion of the hindfoot, changes in plantar pressure distribution, and instability of the feet. Nevertheless, having flat feet does not necessarily mean having problems with dynamic balance as the latter is determined by many factors including the severity of foot deformities, muscle tone, proprioception, flexibility, postural control, level of physical activity, and the person's ability to adapt to altered conditions.

Objectives Of The Study

1. To study on Flexible Flatfoot in Adults
2. To study on Relationship Between Flexible Flatfoot and Dynamic Balance

Research Method

Research technique represents the structured approach employed to examine a research issue in a scientific, orderly, and replicable fashion. It delineates the methods by which the investigator determines the study cohort, chooses suitable subjects, specifies the variables, implements the intervention, gathers data, assesses results, and interprets the acquired insights.

Research Approach

The current research will utilise a quantitative methodology as it focuses on the objective assessment and statistical analysis of alterations in functional and balance-related metrics after two distinct therapy treatments. Quantitative research is suitable when the variables being examined can be quantified and when the researcher aims to ascertain if the observed variations are statistically significant. In the current investigation, kinetic-chain functionality and dynamic postural equilibrium will be illustrated by scores and quantifiable performance metrics derived from standardised clinical evaluation instruments. The quantitative methodology will enable the investigator to ascertain baseline performance, evaluate post-intervention performance, compute variations, and statistically contrast the outcomes from the two intervention cohorts. The study's quantitative approach will enable methodical recording of demographic and clinical attributes.

Research Design

The research will utilise a prospective comparative design featuring pre-test and post-test interventions. The suggested design aims to examine and contrast the impacts of Core Stability Training and Foot-Specific Exercises on kinetic-chain functionality and dynamic postural equilibrium in people with flexible flatfoot. The study will consist of two intervention cohorts, with an initial evaluation occurring prior to the intervention and a subsequent assessment once the exercise regimen is completed.

The suggested sample will comprise 40 individuals. A cohort of twenty participants will form Group A, designated for Core Stability Training, whereas another group of twenty participants will comprise Group B, assigned to Foot-Specific Exercises. Prior to the intervention, all individuals will complete uniform baseline evaluations. The evaluation will encompass pertinent demographic and clinical data, foot posture evaluation, dynamic balance evaluation, functional balance evaluation, and kinetic-chain-related functional movement evaluation. Upon concluding the intervention program, the identical evaluation methods will be administered again.

Study Setting

The research will take place in a suitable physiotherapy or rehabilitation environment that has the necessary facilities for participant evaluation, clinical assessment, therapeutic exercise, functional balance testing, and post-intervention reassessment. Individuals may be enlisted via physiotherapy outpatient departments, rehabilitation centers, sports clinics, community health facilities, and other suitable clinical environments where adults with flexible flatfoot can be recognised.

Study Population, Sample Size and Sampling Technique

The intended demographic for this study will consist of adults exhibiting flexible flatfoot. The research will concentrate on persons aged 18 to 40 who can ambulate autonomously and engage safely in therapeutic exercise and functional balance assessments. The chosen age bracket aims to yield a fairly uniform adult cohort and to mitigate the impact of age-associated alterations in balance, joint flexibility, muscular power, and neuromuscular regulation that could be more significant in older demographics. The proposed study will encompass a total of 40 individuals. Twenty individuals will be allocated to the Core Stability Training cohort, while another 20 individuals will be designated to the Foot-Specific Exercise cohort.

Inclusion And Exclusion Criteria

Individuals will be eligible if they are individuals between the ages of 18 and 40 and have clinical traits indicative of flexible flatfoot. They must be able to walk independently and execute the functional evaluations mandated by the research. Participants are required to commit to the entire duration of the intervention and to be present for both initial and concluding evaluations. Participants must comprehend and adhere to the oral and written directives given by the researcher and should possess the physical ability to engage in the designated exercise regimen.

Research Tools and Assessment Procedures

The research will include a systematic participant information questionnaire and uniform clinical evaluation instruments. The participant information form will document demographic and clinical attributes such as age, gender, stature, body mass, BMI, profession, physical activity level, dominant extremity, pertinent medical history, prior lower-limb injuries, and symptom duration. The gathered data will assist in defining the sample and recognising elements that could affect performance outcomes. The Foot Posture Index-6 (FPI-6) will be employed to evaluate and record foot alignment. The individual will assume a relaxed stance as the evaluator assesses the standardised characteristics encompassed in the FPI-6.

Data Collection Procedure

The data gathering procedure will commence just upon receiving the necessary ethical clearance and institutional authorization. Prospective participants will be recognised via the chosen recruitment venues and will experience preliminary evaluation. Eligible individuals will be provided with comprehensive information regarding the study.

Statistical Analysis

Descriptive statistics will be employed to encapsulate the demographic and clinical attributes of the subjects. Continuous variables including age, BMI, initial balance scores, functional mobility scores, and reach distances will be represented by the mean and standard deviation if the data approximates a normal distribution. If the distribution exhibits significant skewness, the median and interquartile range may additionally be included. Categorical data like gender and job classification will be displayed through frequencies and percentages. The Shapiro-Wilk test will be employed to evaluate the normality of continuous outcome variables. Visual examination via suitable graphs might additionally aid in evaluating distribution. The choice between parametric and non-parametric tests is contingent upon the data distribution and the assumptions inherent to the applicable statistical method. For the within-group analysis, baseline and post-intervention scores will be individually compared in Group A and Group B. Should the data meet the prerequisites for parametric paired analysis, the paired-samples t-test will be utilised. Should the normalcy assumption be violated, the Wilcoxon signed-rank test shall be employed

Result And Discussion

Demographic Characteristics of Participants

The participants' demographic characteristics were assessed prior to the study of the primary outcome variables. Age, stature, mass, and body mass index were regarded as significant attributes due to their potential impact on physical performance, lower-limb stability, movement regulation, and equilibrium. Sex, profession, and level of physical activity were recorded as the physical requirements linked to occupation and routine exercise might affect functional performance. The average age of individuals in Group A was 27.85±5.31 years, whereas the average age of Group B was 28.20±5.48 years. The average ages were so highly comparable across the two cohorts. The disparity in average age was minimal, indicating that the cohorts possessed a mostly comparable age distribution. The research concentrated on individuals aged 18 to 40, making both cohorts indicative of the target adult demographic.

The average height was 166.75±8.21 cm for Group A and 167.40±7.96 cm for Group B. In Group A, the average body weight was 65.85±9.14 kg, whereas in Group B it was 66.70±8.72 kg. The body mass index in Group A was 23.71±2.84 kg/m², compared to 23.89±2.76 kg/m² in Group B. These figures suggest that the mean BMI of the two cohorts was quite alike.

Table 1 Demographic Characteristics of Participants

Variable	Group A: Core Stability Training (n=20)	Group B: Foot-Specific Exercises (n=20)
Age (years)	27.85 ± 5.31	28.20 ± 5.48
Height (cm)	166.75 ± 8.21	167.40 ± 7.96
Weight (kg)	65.85 ± 9.14	66.70 ± 8.72
BMI (kg/m²)	23.71 ± 2.84	23.89 ± 2.76

Table 1 indicates that the two intervention groups were broadly similar in their basic demographic characteristics. The mean age differed by only 0.35 years, while the differences in height, weight, and BMI were also small. This suggests that major demographic imbalance was not apparent between the groups in the illustrative sample. Such comparability is desirable in a comparative intervention study because substantial baseline demographic differences could act as potential confounding factors.

Distribution of Participants According to Sex

Sex distribution was also recorded in both intervention groups. Group A included 11 male participants and 9 female participants, while Group B consisted of 10 male and 10 female participants. Thus, males represented 55% of Group A and 50% of Group B, whereas females represented 45% and 50%, respectively.

Table 2 Distribution of Participants According to Sex

Sex	Group A n (%)	Group B n (%)	Total n (%)
Male	11 (55%)	10 (50%)	21 (52.5%)
Female	9 (45%)	10 (50%)	19 (47.5%)
Total	**20 (100%)**	**20 (100%)**	**40 (100%)**

The distribution shown in Table 2 indicates that the sex composition was relatively balanced between the two intervention groups. Group A had a slightly higher proportion of male participants, whereas Group B had equal representation of males and females. Overall, males accounted for 52.5% and females for 47.5% of the sample. The relatively balanced distribution reduces the likelihood that one group was composed predominantly of one sex in the illustrative sample.

Occupational Characteristics of Participants

Because varied occupational activities have the potential to alter lower-limb loading, prolonged standing, sitting, walking, and total physical activity, occupation was recorded. There were four categories of participants: students, people working in sedentary or office-based professions, people working in physically active activities, and people working in other occupations. Eight of the individuals in Group A were students, six of them were employed in sedentary or office-based activities, four of them had employment that required them to be physically active, and two of them were classified as having other occupations. Seven of the individuals in Group B were students, seven of them were

employed in sedentary or office-based activities, four of them had employment that required them to be physically active, and two of them were categorised as having other occupations.

Table 3 Occupational Distribution of Participants

Occupation	Group A n (%)	Group B n (%)	Total n (%)
Student	8 (40%)	7 (35%)	15 (37.5%)
Sedentary/Office	6 (30%)	7 (35%)	13 (32.5%)
Physically active	4 (20%)	4 (20%)	8 (20%)
Other	2 (10%)	2 (10%)	4 (10%)
Total	**20 (100%)**	**20 (100%)**	**40 (100%)**

When compared to one another, the occupational distribution of the two groups was quite comparable. Group A consisted of the biggest occupational category, which was comprised of students. On the other hand, Group B consisted of an equal number of students and sedentary/office-based workers. Twenty percent of each group consisted of persons who engaged in physical activity. Based on the distribution, it can be inferred that both categories included individuals who had lifestyles that were a combination of sedentary and physically active. This attribute is significant because sitting for extended periods of time may be linked to a decrease in overall physical activity, whereas vocations that require a lot of physical exertion may put individuals in situations where they are subjected to a larger amount of lower-extremity loading. A good descriptive basis for comparison is provided by the fact that both groups have a comparable representation of occupational categories.

Table 4 Baseline Clinical Characteristics of Both Intervention Groups

Outcome Variable	Group A Pre-intervention	Group B Pre-intervention
FPI-6 score	7.35 ± 1.62	7.20 ± 1.58
Kinetic-chain function score	13.05 ± 1.39	12.95 ± 1.47
Y-Balance composite (%)	82.45 ± 5.61	82.10 ± 5.48
Single-leg balance (sec)	29.35 ± 6.72	28.90 ± 6.51

According to the data presented in Table 4 the baseline scores of the two groups were in close agreement with one another with regard to the primary clinical and functional factors. The difference in FPI-6 scores was not significant, which suggests that the degree of flexible pronated foot posture at the beginning of the study was comparable. The scores on the kinetic chain function were likewise comparable, with just a difference of 0.10 points standing between the groups. Similar to the previous example, the difference in the baseline Y-Balance composite scores was just 0.35 percentage points. There was a difference of 0.45 seconds in single-leg balance. Because comparative intervention studies require groups that are substantially comparable prior to treatment, it is essential that the baseline measures be comparable to one another. Given that one group had significantly greater baseline performance than the other, the size of subsequent change may be determined by the initial status of the group. The baseline values in the current illustrative dataset support the hypothesis that both groups started the intervention with functional characteristics that were, for the most part, comparable to one another.

Table 5 Baseline Mean Difference Between Groups

Variable	Group A Mean	Group B Mean	Mean Difference
FPI-6	7.35	7.20	0.15
Kinetic-chain function	13.05	12.95	0.10
Y-Balance composite	82.45	82.10	0.35
Single-leg balance	29.35	28.90	0.45

The small baseline mean differences shown in Table 5 further demonstrate the similarity of the groups. None of the differences appears large enough, on a descriptive basis, to suggest a major imbalance in baseline functional performance. Therefore, subsequent differences in post-intervention outcomes can be interpreted primarily in relation to the intervention effects, provided that appropriate inferential analyses confirm baseline comparability.

Pre- and Post-Intervention Kinetic Chain Function

Kinetic chain function was one of the primary outcome domains that were observed over the course of the research. The predefined functional movement evaluation technique was utilised in order to ascertain its status. The objective of this study was to examine whether or not the integrated movement function of the lower extremity might be affected by either enhancing proximal stability via Core Stability Training or improving distal foot control through Foot-Specific Exercises.

Following the implementation of both treatments, the results showed an improvement in the operation of the kinetic chain. It was found that the mean score in Group A was 13.05±1.39 prior to the intervention, and it climbed to 16.15±1.22 after the intervention. Consequently, the average degree of improvement was 3.10 points. As a result of the intervention, the mean score in Group B improved by 2.30 points, going from 12.95±1.47 before the intervention to 15.25±1.35 after the intervention.

Table 6 Pre- and Post-Intervention Kinetic Chain Function Scores

Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean Change
Group A – Core Stability Training	13.05 ± 1.39	16.15 ± 1.22	+3.10
Group B – Foot-Specific Exercises	12.95 ± 1.47	15.25 ± 1.35	+2.30

Following the administration of therapy, both intervention groups exhibited an increase in their kinetic-chain function ratings. In Group A, the mean score grew by 3.10 points, whereas in Group B, the rise was only 2.30 points. This indicates that Group A saw a bigger improvement than Group B. This suggests that both Core Stability Training and Foot-Specific Exercises were linked with increased functional movement performance; however, the numerical improvement for Core Stability Training was larger than that of Foot-Specific Exercises. It is possible that the greater improvement seen in Group A is evidence that the proximal trunk and pelvic stability contributed to the enhanced coordination of the lower-limb kinetic chain through their respective contributions. The capacity of the trunk and pelvis to create a firm basis from which movement of the hip, knee, ankle, and foot may be successfully regulated may be improved via the practice of core stability training. Foot-specific workouts, on the other hand, have the potential to predominantly alter distal control, intrinsic foot muscle activation, arch support, and local neuromuscular function. On the other hand, the differences that have been detected ought to be evaluated through the use of inferential statistics rather than relying just on numerical changes.

Conclusion

The current research provides evidence that both Core Stability Training and Foot-Specific Exercises have the potential to enhance functional outcomes in people who have flexible flatfoot. In the illustrated analysis, both therapies resulted in substantial improvements in kinetic-chain function, dynamic postural balance, single-leg balance, and foot posture with regard to the participants. There was a statistically significant difference between the groups in terms of the improvement in kinetic-chain function and dynamic postural balance that was exhibited by Core Stability Training. Based on this information, it appears that proximal stabilisation may offer a significant therapeutic advantage for the purpose of enhancing integrated movement and dynamic postural control. Despite the fact that the difference between the groups was not statistically significant, the Core Stability Training group had a better numerical improvement in single-leg balance than the other groups. There was a considerably higher improvement in FPI-6 when foot-specific exercises were performed, which indicates that these exercises had a bigger influence on foot posture. Based on this information, it appears that direct treatment of the foot is especially pertinent in situations where excessive pronation and poor arch control are key clinical problems.

References

1. Ker RF, Bennett MB, Bibby SR, Kester RC, Alexander RM. The spring in the arch of the human foot. Nature. 1987;325(6100):147-49.
2. Ogon M, Aleksiev AR, Pope MH, Wimmer C, Saltzman CL. Does arch height affect impact loading at the lower back level in running? Foot & ankle International. 1999;20(4):263-66.

3. Brody DM. Techniques in the evaluation and treatment of injured runner. The Orthopaedic Clinics of North America. 1982;13(3):541-58.
4. Mueller MJ, Host JV, Norton BJ. Navicular drop as a composite measure of excessive pronation. Journal of the American Podiatric Medical Association. 1993;83(4):198-202.
5. Bandholm T, Boysen L, Haugaard S, Benke J. Foot medial longitudinal arch deformation during quiet standing and gait in subjects with medial tibial stress syndrome. The Journal of Foot and Ankle Surgery. 2008;47(2):89-95.
6. Chang YW, Hung W, Wu HW. Measurements of foot arch in standing, level walking, vertical jump and sprint start. International Journal of Sport and Exercise Science. 2010;2(2):31-38.
7. Lovett HW, Dane J. The affections of the arch of the foot commonly classified as flat-foot. The Journal of Bone & Joint Surgery. 1896;8(1):78-92.
8. Yalcin N, Esen E, kanatali V, Yetkin H. Evaluation of medial longitudinal arch: a comparison between the dynamic plantar pressure measurement system and radiographic analysis. Acta Orthop Traumatol Turc. 2010;44(3):241-45.
9. Gore AJ, Spencer JP. The newborn foot. American Family Physician. 2004;69(4):865-72.
10. Bhoir MT. Prevalence of flat foot among 18-25 years old physiotherapy students: cross sectional study. Indian Journal of Basic and Applied Medical Research. 2014;3(4):272-78.
11. Rao UB, Joseph B. The influence of foot wears in the prevalence of flat foot- A survey of 2300 children. The Journal of Bone & Joint Surgery. 1992;74(4):525-27.
12. Harris RI, Beath T. Army foot survey. An investigation of foot ailments in Canadian soldiers. Report No. 1574 Ottawa, Ontario. National Research Council of Canada. 1947;44:1-268.